

Using Maximal Isometric Force to Determine the Optimal Load for Measuring Dynamic Muscle Power

Barry A. Spiering¹, Stuart M.C. Lee¹, Ajitkumar P. Mulavara², Jason R. Bentley¹, Roxanne E. Nash³, Joseph Sinka¹, Jacob J. Bloomberg⁴

¹Wyle Integrated Science and Engineering Group, Houston, TX; ²Universities Space Research Association, Houston, TX; ³University of Houston, Houston, TX; ⁴National Aeronautics and Space Administration, Houston, TX

Email: Barry.Spiering-1@nasa.gov

Abstract

Maximal power output typically occurs when subjects perform ballistic exercises using loads of ~30% of one-repetition maximum (1-RM). However, performing 1-RM testing prior to power measurement requires considerable time, especially when testing involves multiple exercises. Maximal isometric force (MIF), which requires substantially less time to measure than 1-RM, might be an acceptable alternative for determining the optimal load for power testing. **PURPOSE:** To determine the optimal load based on MIF for maximizing dynamic power output during leg press and bench press exercises. **METHODS:** Twenty healthy volunteers (12 men and 8 women; mean ± SD age: 31 ± 6 y; body mass: 72 ± 15 kg) performed isometric leg press and bench press movements, during which MIF was measured using force plates. Subsequently, subjects performed ballistic leg press and bench press exercises using loads corresponding to 20%, 30%, 40%, 50%, and 60% of MIF presented in randomized order. Maximal instantaneous power was calculated during the ballistic exercise tests using force plates and position transducers. Repeated-measures ANOVA and Fisher LSD *post hoc* tests were used to determine the load(s) that elicited maximal power output. **RESULTS:** For the leg press power test, 6 subjects were unable to be tested at 20% and 30% MIF because these loads were less than the lightest possible load (i.e., the weight of the unloaded leg press sled assembly [31.4 kg]). For the bench press power test, 5 subjects were unable to be tested at 20% MIF because these loads were less than the weight of the unloaded aluminum bar (i.e., 11.4 kg). Therefore, these loads were excluded from analysis. A trend ($P=0.07$) for a main effect of load existed for the leg press exercise, indicating that the 40% MIF load tended to elicit greater power output than the 60% MIF load (effect size = 0.38). A significant ($p \leq 0.05$) main effect of load existed for the bench press exercise; post hoc analysis indicated that the effect of load on power output was: 30% > 40% > 50% = 60%. **CONCLUSION:** Loads of 40% and 30% of MIF elicit maximal power output during dynamic leg presses and bench presses, respectively. These findings are similar to those obtained when loading is based on 1-RM.

Introduction

Maximal power capabilities strongly predict functional (3) and athletic performance (4). Therefore, substantial research has sought to determine the optimal load with which to test maximal power capabilities. Although some controversy exists (2), peak instantaneous power output is maximized when athletes perform ballistic movements using loads corresponding to ~30% of 1-RM (1). However, measuring 1-RM is not always feasible/appropriate. For instance, 1-RM testing prior to power measurement requires considerable time, especially when subjects are tested using multiple exercises; and 1-RM testing might be contraindicated in some populations (i.e., frail elderly, during injury rehabilitation, post-unloading).

Maximal isometric force (MIF) is an attractive alternative strength measure for determining the optimal load for power testing due to lower time requirements and the inherent safety of the measurement (e.g., it does not involve eccentric muscle actions). Therefore, the purpose of this study was to determine the optimal load based on MIF for maximizing dynamic power output during ballistic leg presses and bench presses.

Methods

Experimental Design. Subjects performed isometric leg presses and bench presses, during which MIF was measured using force plates. Subjects subsequently performed ballistic, concentric-only leg presses and bench presses using loads corresponding to 20%, 30%, 40%, 50%, and 60% of MIF (presented in randomized order), during which maximal instantaneous power was measured using force plates and position transducers.

Subjects. Twenty healthy volunteers (mean ± SD; 12 men, 8 women, age: 31 ± 6 years, body mass: 72 ± 15 kg) consented to participate in this investigation. Test protocols and procedures were reviewed and approved by the Johnson Space Center's Committee for the Protection of Human Subjects.

Procedures. Data were obtained using a leg press device (Nebula Fitness Equipment, Versailles, OH) and bench press power cage (Fitness Technology, Skye, SA, Australia). Both devices were equipped with a force plate (Kistler Instrument Corp., Amherst, NY) and position transducer (Fitness Technology).

Analyses. Data were analyzed using a repeated-measures ANOVA. In the event of a significant F score, the Fisher LSD post-hoc test was used to determine pair-wise differences. The criterion for statistical significance was $P<0.05$.

Results

Maximal Isometric Force
MIF values are presented in **Table 1**.

Maximal Instantaneous Power Output
Leg Press. Six subjects were unable to be tested at 20% and 30% MIF because these loads were less than the lightest possible load (i.e., the weight of the unloaded leg press sled assembly, 31.4 kg). Therefore, these loads were excluded from analysis.

ANOVA revealed a trend ($p = 0.07$) for a main effect of load; subsequent analysis indicated that power output during the 40% MIF attempt tended to be greater than power output during the 60% MIF attempt (effect size = 0.38) (**Figure 1**).

Bench Press. Five subjects were unable to be tested at 20% MIF because these loads were less than the weight of the unloaded aluminum bar (11.4 kg). Therefore, these loads were excluded from analysis.

ANOVA revealed a significant main effect of load; post hoc analysis indicated the following order: 30% > 40% > 50% = 60% (**Figure 2**).

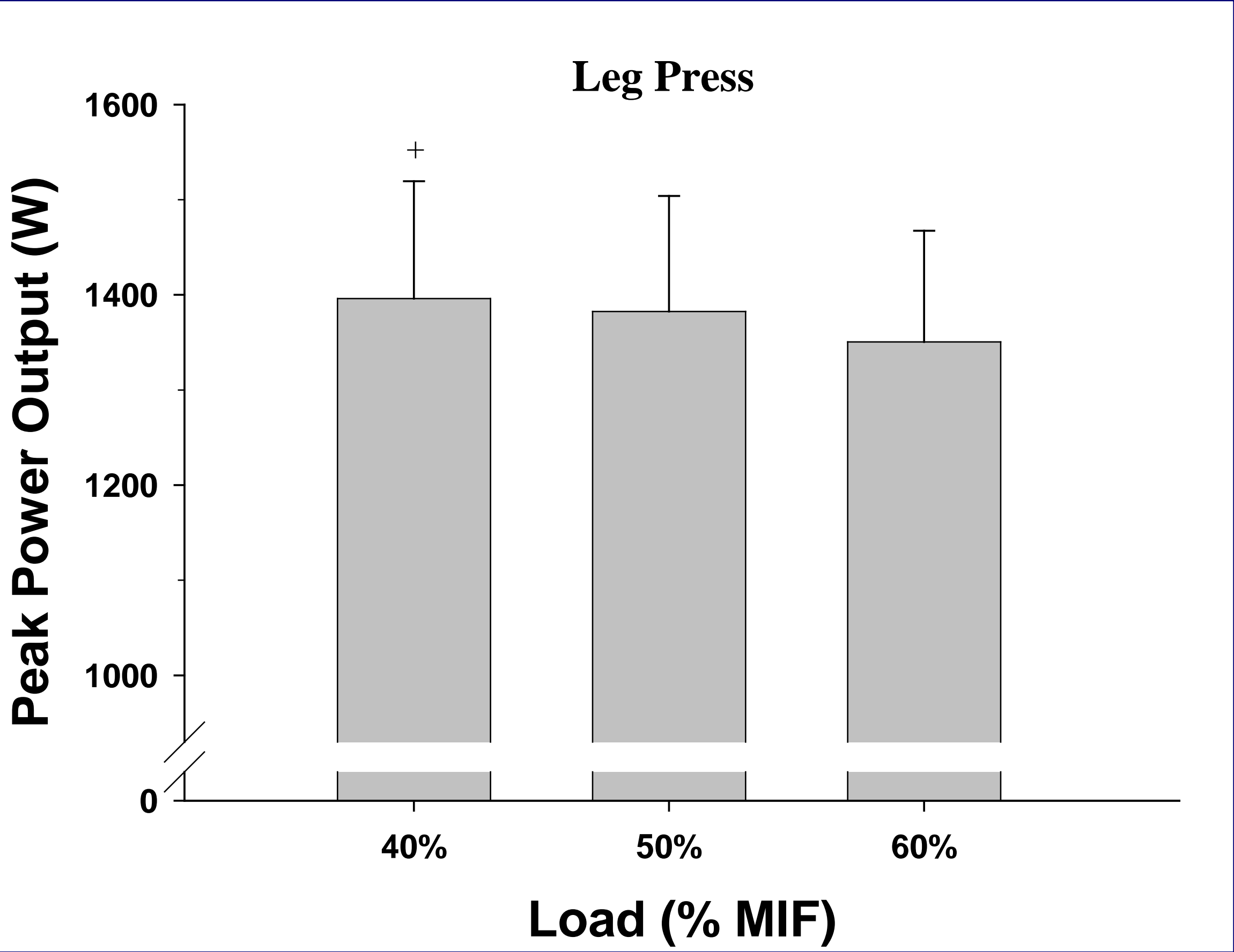


Figure 1. Peak power output (mean ± SE) during ballistic leg presses using different loads based on a percentage of maximal isometric force (MIF). “+” denotes trend ($P=0.07$) for difference in power output compared to 60% MIF load.

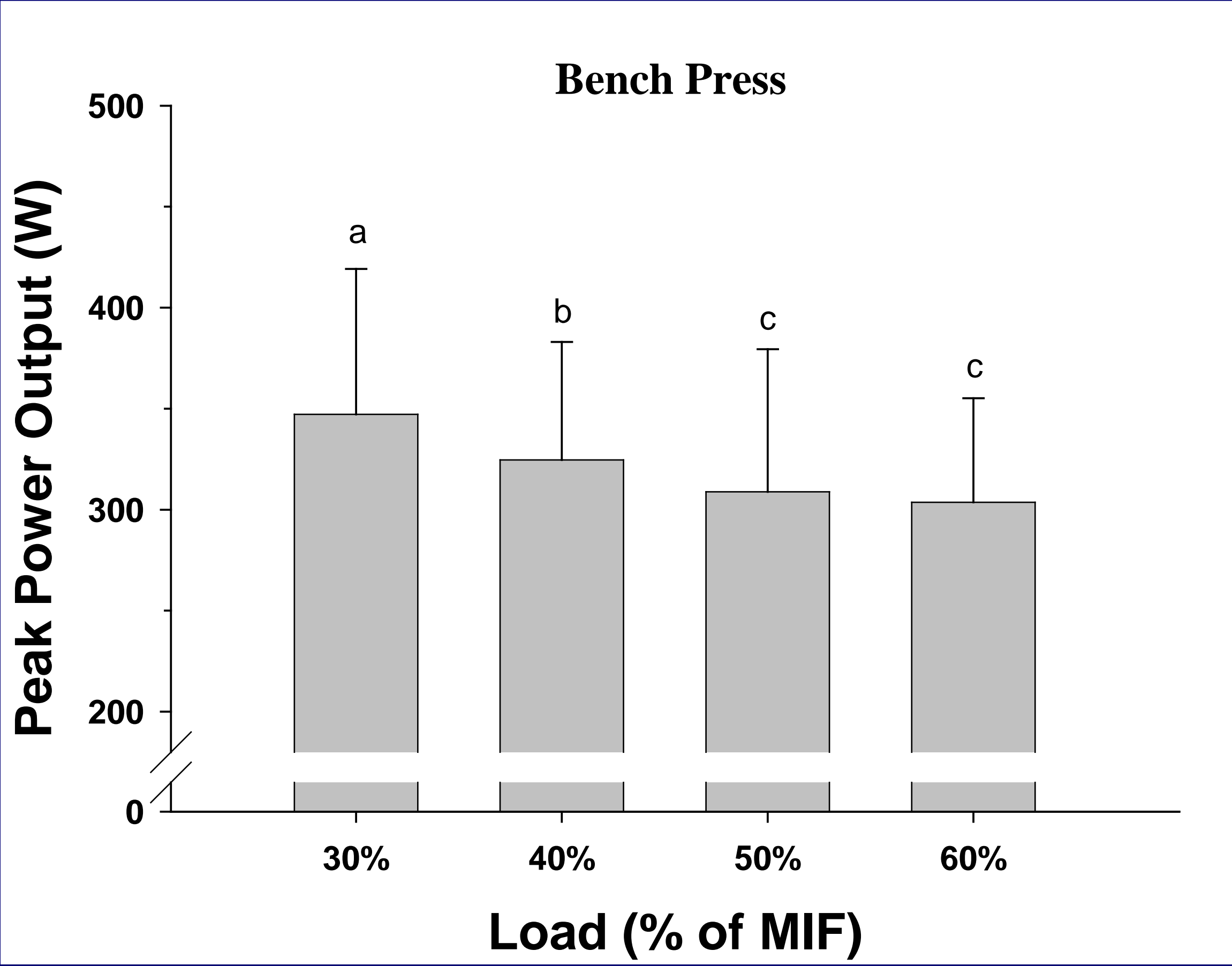


Figure 2. Peak power output (mean ± SE) during ballistic bench presses using different loads based on a percentage of maximal isometric force (MIF). Unlike symbols denote significant ($P<0.05$) differences in power output between loads.

Table 1. Maximal isometric force values (mean ± SD).

	Leg Press (N)		Bench Press (N)	
Females (n = 8)	398	53	188	50
Males (n = 12)	764	130	427	90
Total (n = 20)	618	212	331	142

Conclusions

Maximal isometric force (MIF), which requires little time and is inherently safe to perform, can be used as an alternative strength measure for determining the optimal load for power testing.

Loads of 40% and 30% of MIF elicit maximal power output during ballistic, concentric-only leg presses and bench presses, respectively.

The optimal relative load for measuring peak power output (i.e., 30-40% MIF) is similar to that which is recommended when loading is based on 1-RM (i.e., ~30% 1-RM) (1).

References

1. Dugan EL, Doyle TL, Humphries B, Hasson CJ, Newton RU. Determining the optimal load for jump squats: a review of methods and calculations. J Strength Cond Res. 2004 Aug;18(3):668-74.
2. Kawamori N, Haff GG. The optimal training load for the development of muscular power. J Strength Cond Res. 2004 Aug;18(3):675-84.
3. Puthoff ML, Janz KF, Nielson D . The relationship between lower extremity strength and power to everyday walking behaviors in older adults with functional limitations. J Geriatr Phys Ther. 2008; 31(1):24-31.
4. Smirniotou A, Katsikas C, Paradisis G, Argeitaki P, Zacharogiannis E, Tziortzis S. Strength-power parameters as predictors of sprinting performance. J Sports Med Phys Fitness. 2008;48(4):447-54.

Acknowledgements

This work was supported by the National Aeronautics and Space Administration.

We would like to thank Kirk English, Mark Leach, and Leah Stroud for invaluable assistance during data collection and an enthusiastic group of volunteers for participation in the study. Results of the present study do not constitute endorsement by ACSM.